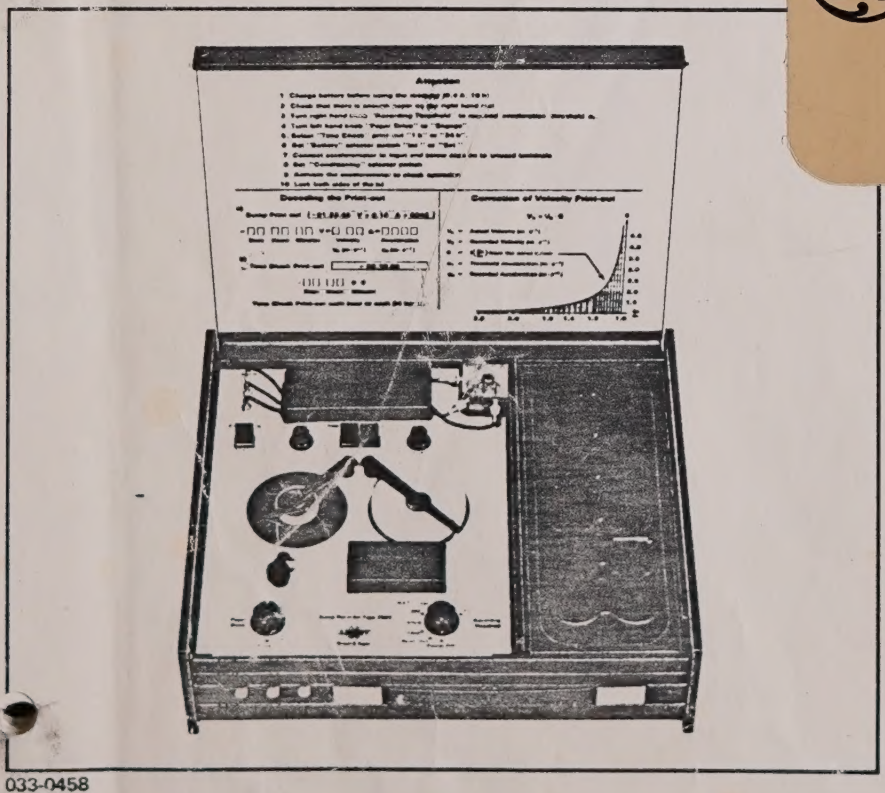
Instruction Manual

2503

Bump Recorder Type 2503



Quick-rental® instruments

GENERAL ELECTRIC CO.
1138 164th PLACE
HAMMOND, IN 46320
PHONE (312) 780-2994

A completely self contained measuring instrument that records the level and time of occurrence of mechanical shocks. Its primary application is to monitor goods items during transport where rough handling methods often expose them to higher shock levels than they are designed to withstand.

Shocks occurring in any direction are picked up by a triaxial transducer, and if they exceed a chosen trigger level, their maximum velocity and acceleration together with the time of occurrence is printed out on a 6 mm wide paper tape.

When fitted with an optional high sensitivity pickup the recorder is ideal for monitoring ground and building vibrations due to heavy traffic, explosive detonations, pile driving etc.

185-T FOREST ST
MARLBOROUGH, MA. 01752

Brüel & Kjær
617-481-7000

033-0458

This apparatus has been designed and tested according to Class III of IEC Publication 348, Safety Requirements for Electronic Measuring Apparatus, and has been supplied in safe condition. The present instruction manual contains information and warnings which should be followed by the user to ensure safe operation and to retain the apparatus in safe condition.

BUMP RECORDER
TYPE 2503

June 1978

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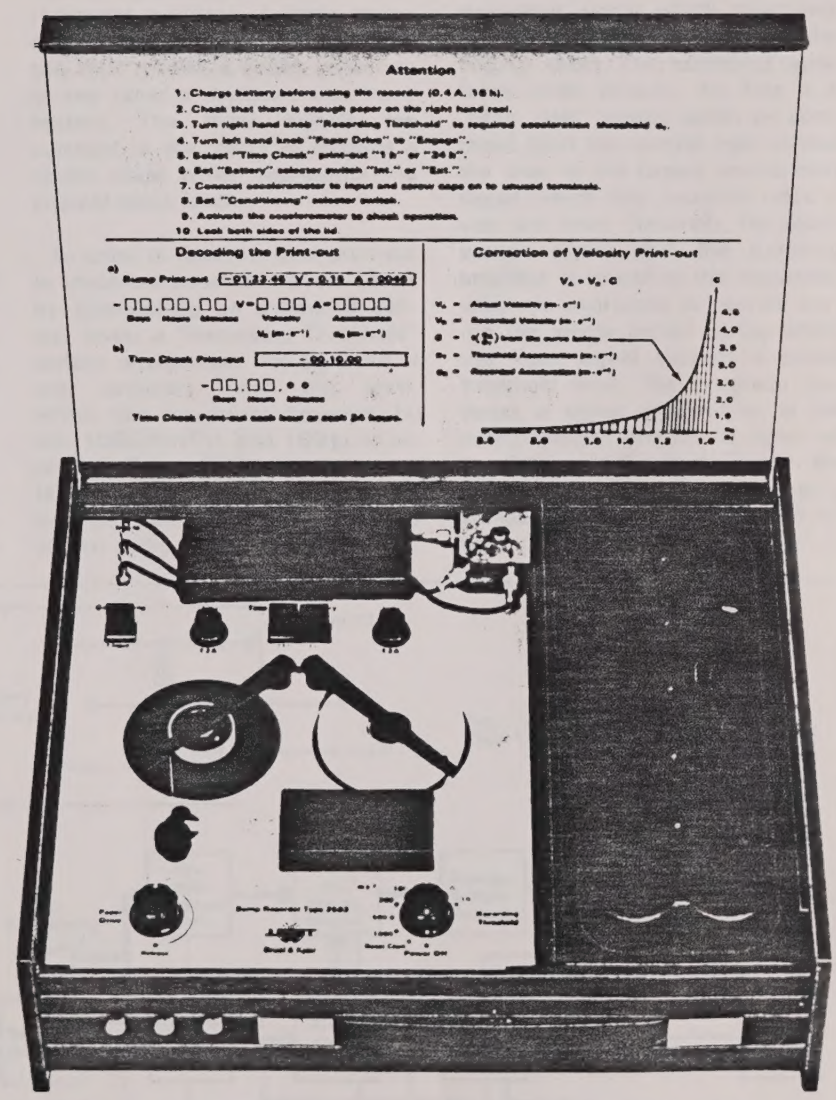
type 2503

Bump Recorder


Attention
1. Charge battery before using the recorder (0.4 A, 18 h).
2. Check that there is enough paper on the right hand reel.
3. Turn right hand knob "Recording Threshold" to required acceleration threshold a_s.
4. Turn left hand knob "Paper Drive" to "Engage".
5. Select "Time Check" print-out "1 h" or "24 h".
6. Set "Battery" selector switch "Int." or "Ext.".
7. Connect accelerometer to input and sensor caps on to unused terminals.
8. Set "Conditioning" selector switch.
9. Activate the accelerometer to check operation.
10. Lock both sides of the lid
Decoding the Print-out
Correction of Velocity Print-out
Time Check Print-out each hour or each 24 hours.

FEATURES:

- Digital print-out indicates time of occurrence, maximum acceleration ($\propto$ force), and maximum velocity ($\propto$ energy) of bump events
- Selectable uni- or omnidirectional monitoring
- Wide measuring ranges
- Triaxial accelerometer included
- Accelerometer(s) can be positioned remotely or internally
- Adjustable recording threshold from 10 m/s² (1 g) to 1000 m/s² (100 g) peak
- Time-check print-out every hour or alternatively, every 24 hours
- High-reliability electronic operation
- Battery power supply covers 18 days operation
- External power supply can be connected to cover longer periods
- Battery charger and rechargeable batteries included
- Paper roll can contain 540 complete data print-outs
- Can be sealed to guard against unauthorised tampering
- Reusable container protects the instrument when in use

USES:

- Monitoring shocks experienced by goods during transport
- Measurements in packaging design and development
- Investigation of transport methods and routes
- Identification of careless handlers
- May support claims for damage in transit
- Investigation of mechanical handling systems
- Recording ground vibrations

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The Bump Recorder Type 2503 is designed to measure and record the level and time of occurrence of mechanical shocks. Its primary application is in the field of goods transportation where rough handling methods often expose packages to higher shock levels than the transported object is designed to withstand. By establishing the severity of shocks occurring under transport it can be estimated whether damage is likely to have taken place, and if so, the time of occurrence will indicate where the responsibility lies.

The 2503 consists of a battery-operated measuring instrument and strip recorder housed in a sturdy case and is intended to be transported with the goods to be monitored. The shock pick-up, an acceleration sensitive device called an accelerometer, is normally mounted on the transported object with a flexible cable connection to the measuring instrument, but it may also be mounted inside the instrument case itself.

Goods under transport may be subjected to bumps in any direction, therefore it is not normally sufficient to monitor in one direction only. The 2503 is equipped with a triaxial accelerometer which simultaneously monitors in three mutually perpendicular directions and can thus resolve a shock, occurring in any random direction, into three vectors. The three signals are summed in the 2503 to produce a single value which represents the original shock level.

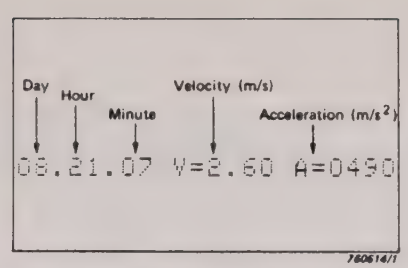


Fig.1. A typical print-out from the 2503

In order to limit the data print-out to shock events which have a severity approaching an estimated serious level, a "Recording Threshold" control is provided. The print-out is only activated when this level, which can be preset between 10 and 1000 m/s² (1 and 100 g), is exceeded. The record strip then contains only significant data. A typical print-out from the Bump Recorder is shown in Fig.1.

Description

Operation

Reference is made to the block diagram in Fig.2 and the operating sequence chart in Fig.3.

The three input signals from the monitoring accelerometer(s) are individually conditioned in the input charge amplifiers and then rectified. The output from the three channels are then summed to obtain a single equivalent signal which represents the acceleration-time history of the original shock. This combined signal feeds three circuits: the first is a "Max. Hold" circuit which on command from the control logic retains the level of the largest acceleration signal which has occurred since it was last reset. Secondly, the acceleration signal from the summing amplifier is routed to the integrator, which is instructed to operate during the whole period during which the input signal exceeds a preset threshold level. The integrator produces a signal proportional to the bump velocity, and this is again fed to a "Max. Hold" circuit. Thirdly, the acceleration signal is routed to a comparator which monitors the level.

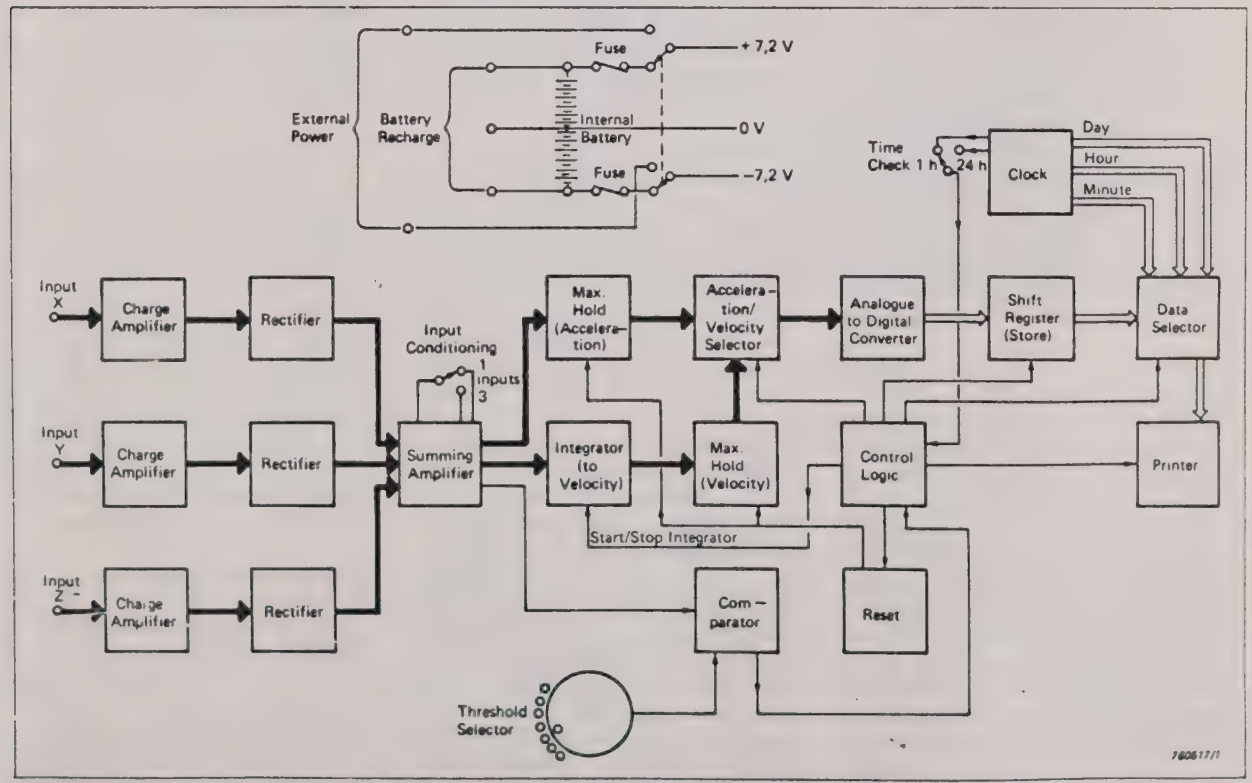


Fig.2. Simplified block diagram of Bump Recorder Type 2503

Immediately the level preset on the threshold selector is exceeded, the comparator informs the control logic, which starts the integrator and instructs the velocity and acceleration Max. Hold circuits to retain the maximum level of the pulse which is building up. As the pulse dies away, the trigger level is crossed again, which is the event that prompts the control logic to initiate the readout sequence. The velocity and acceleration levels held in the Max. Hold circuits are then released by the acceleration/velocity selector and converted to digital values so that they can be held in a shift register (store). The data selector then routes the data to the printer, first the day, hour and minute of print-out, then the stored maximum velocity and maximum acceleration levels are printed out.

During the 4 seconds taken for the data to be printed out, the instrument is still collecting information. Immediately the Max. Hold circuits have passed on their information through the analogue to digital converter to the digital store, they are free to collect new bumps. If the trigger level is again exceeded during the 4 second print-out period the Max. Hold circuits will hold the level of the most severe bump occurring during that time; these data are routed to the printer immediately it is free from printing the previous bump event.

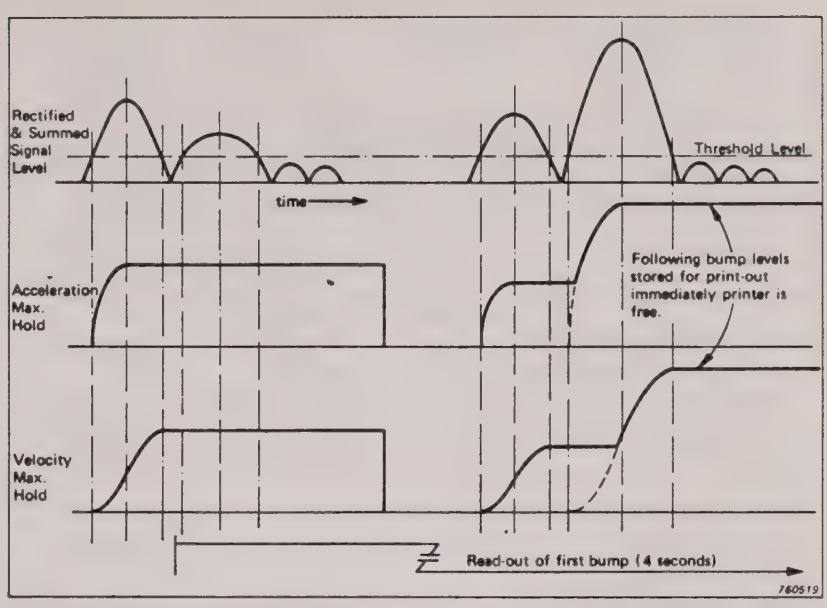


Fig.3. Chart demonstrating the operating sequence of Bump Recorder Type 2503 when an initial bump is closely followed by several other bumps, some of which exceed the preset threshold level

Pick-up and Input Facilities

Supplied as standard equipment with the 2503 is a triaxial accelerometer pick-up, Brüel & Kjær Type 4321. This device consists of three individual accelerometer elements with their principal axes mounted perpendicularly to each other, so that it detects bumps in three mutually perpendicular directions. Each element is of the Uni-Gain® type, which means that their sensitivities are all equal (at 1 pC/ms^{-2}) within a 2% tolerance.

An input selector switch is provided which conditions the gain of the summing amplifier so that measurements can be made in a single direction if desired.

In normal circumstances, the accelerometer will be attached to a critical part of the goods transported. Fixing to a flat surface, can be accomplished either with a 4 mm screw passing through the accelerometer body or by means of a 10 — 32 UNF stud screwed into the base. Alternatively, the accelerometer may be used mounted in the instrument case itself. A solid mounting surface with rigid connection to the body of the instrument case is provided for this purpose.

Three standard accelerometer cables 1,2 m long and three reinforced accelerometer cables 3 m long are included with the 2503. These can be extended or replaced by longer cables, and as the 2503 has a charge amplifier input, various cable lengths can be used without affecting the instrument's sensitivity.

Occasionally it may be desired to mount three separate accelerometers on different individual parts of a goods item. B & K Accelerometer Type 4371 is recommended for this purpose. The sensitivity of the Bump Recorder can be increased by a factor of 10 by using a single or three accelerometers of the Type 4370. Further details of B & K Accelerometers and cables are contained in a comprehensive data brochure covering the B & K Accelerometer range.

Pick-up for Ground Vibrations

By using the Low g Accelerometer Type 8306 with the Bump Recorder, the measuring sensitivity is increased a thousand times so that the acceleration measuring range covers 0,01 to 5 m/s^2 (0,001 to 0,5 g) and the velocity range covers 0,3 mm/s to 14 mm/s. The ability to record the occurrence of such low levels allows the 2503 to be used for monitoring ground vibrations due to heavy traffic, explosive detonations, seismic activity etc. The Low g Accelerometer Type 8306 requires an external power supply of 28 V DC 2 mA which may be provided by a separate external battery pack.

Printer

The thermal dot-printer prints out the data on a 6 mm wide strip of heat sensitive paper. Each character is built up from a 5 × 7 dot matrix. A full print-out consisting of 28 characters and spaces takes 4 seconds. About 540 complete data events can be recorded on each roll of paper. Additional rolls of paper can be ordered in packages of 20 under reference No. QP 7000. A photo-cell detector prevents power being applied to the print-head and paper drive motor when the recording paper is exhausted.

tive time keeper for the shock events recorded on the paper strip. The clock is reset at the beginning of each "journey" and from then on keeps time relative to the instant of resetting. Each bump level print-out is preceded by a print-out of the relative time of occurrence in days, hours, and minutes. Furthermore, the clock is programmed to print-out the time each hour or 24 hours, as selected, as an operational check on a large part of the system. If the instrument is switched off the clock is automatically reset.

Operating Range

The Bump Recorder Type 2503 is designed to record the full range of shocks likely to occur during the transportation of goods. The measuring limits are shown graphically in Fig.4. Additional measuring errors can be expected if the accelerometers are subjected to shocks lying outside the specified area.

Three-Axis Summation

By using a triaxial accelerometer with mutually perpendicular sensitive axes, bumps occurring in any direction in space (see Fig.5) can be measured with reasonable accuracy.

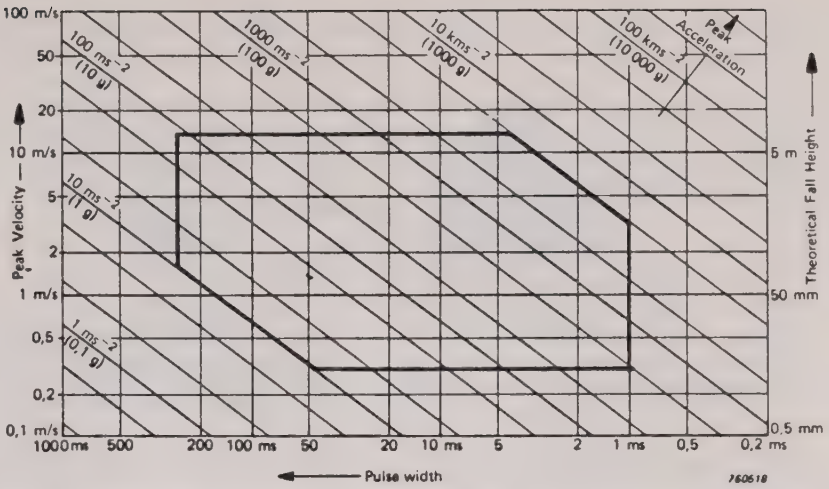


Fig.4. Operating ranges for the Bump Recorder Type 2503. The right hand scale of Theoretical Drop Height is sometimes used as a measure of maximum velocity. The Theoretical Drop Height $h = \frac{v^2}{2g}$ where v = maximum velocity and g = the acceleration due to gravity

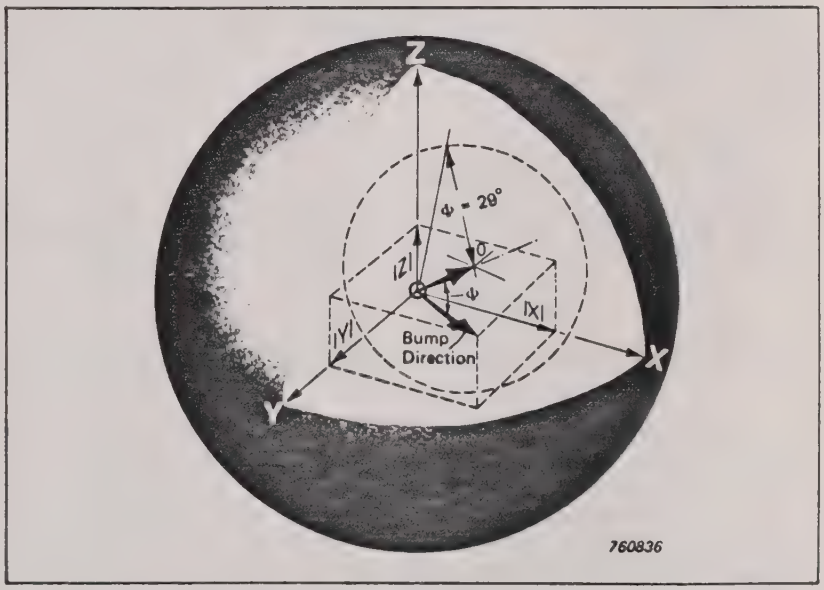


Fig.5. By monitoring in three mutually perpendicular directions the Bump Recorder Type 2503 can resolve the level of bumps occurring in any random direction in space

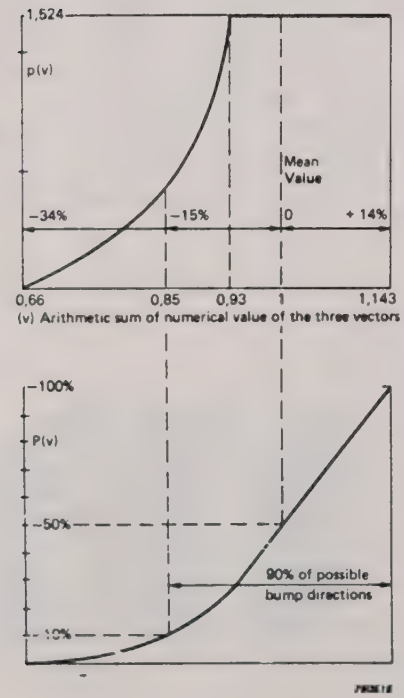


Fig.6. Probability Density and Cumulative Distribution Curves for the arithmetic sum of the numerical values of three mutually perpendicular vectors which represent a single vector occurring in any direction in a spatial coordinate system

The numeric values of the three accelerometer signals are summed in such a way in the 2503 that the true bump acceleration is approximated. This simple arithmetic summing gives a measuring error which for 90% of all possible bump directions will be within + 14% to —15%. For the remaining 10% of possible bump directions the summing error will be between —15% and —34%. Fig. 6 shows the probability density and cumulative distribution curves for the summation.

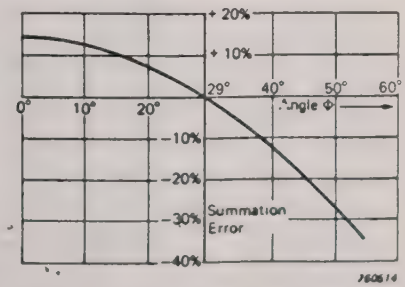


Fig.7. Summation error of Type 2503 as a function of the bump angle Φ

In practical terms this means that the greatest error (—34%) occurs when the bump direction coincides with one of the three accelerometer axes, X, Y & Z, (see Fig.5). The error diminishes as the angle Φ between the bump direction and the radius line to the point 0, which lies at the centre of the curved surface of the 1/8 sphere, approaches Φ_o (= 29°). The error then begins to increase as Φ approaches 0°. Fig.7 shows the summation error as a function of the angle Φ.

Velocity Print-out Correction

The maximum velocity level is obtained by electronically integrating the acceleration pulse which has exceeded the preset threshold. The process of integration is in fact the measurement of the area under the acceleration-time curve. As the integrator only operates during the time which the input signal exceeds the threshold level, the acceleration-time history is not integrated during the beginning and end of the pulse. The area 'lost" is dependent on the relative level of the trigger threshold and the actual signal max. level. This phenomenon is demonstrated in Fig.8. Where the threshold level is only marginally exceeded, the error should be compensated for correct results. The velocity level printed out is multiplied by a correction factor which is extracted from the curve printed on the inside of the instrument case lid, see Fig.9.

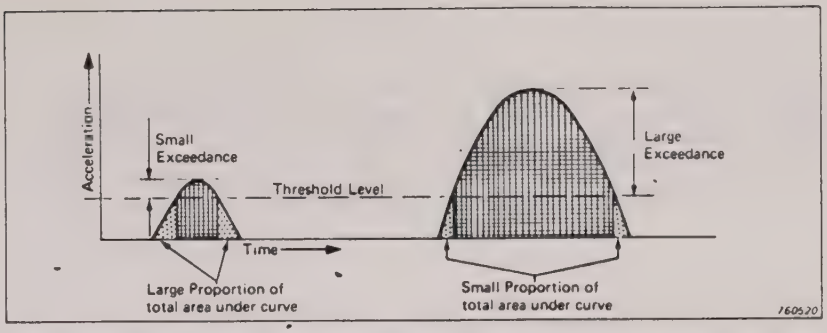


Fig.8. Sketch showing how the integrated portion of the acceleration-time curve (and hence the velocity level printed out) is dependent on the ratio of threshold level to maximum recorded acceleration level

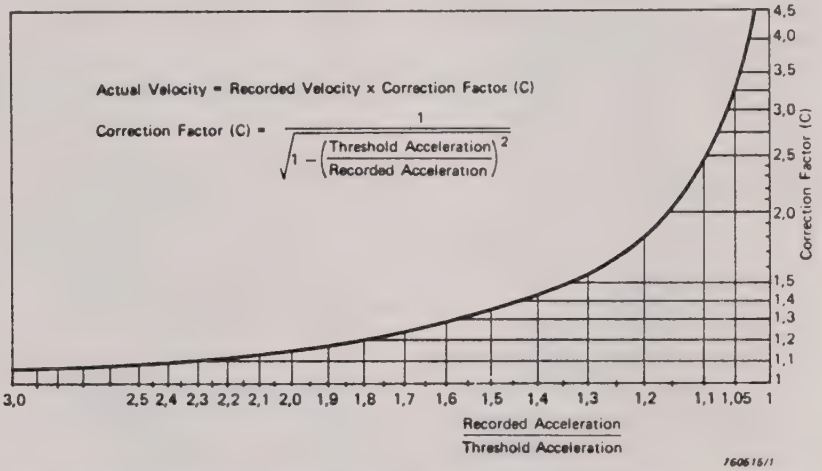


Fig.9. Chart for determining the actual impact velocity from the velocity level printed out when the threshold level is marginally exceeded

Fig.10. The moulded polyurethane foam container, in which the 2503 is delivered, can be used to protect the instrument when in use

Instrument Mounting

The 2503 is delivered in a moulded polyurethane foam container which can be utilized for protecting the instrument when it is in use (See Fig.10.) The nature of this packing material is such that it can recover after being deformed by shocks, and therefore continues to protect the instrument. Leather or elastic straps will normally be used for securing the instrument to the transported object or packing case.

Tamper Proofing

Two 2 mm holes are provided in the body of the instrument to enable the lid to be wired down and sealed, with for example lead seals, to guard against unauthorized interference. In this connection it can also be noted that if the instrument is switched off, the clock will be automatically reset.

Power Supply

The internal power supply consists of two banks of six 3,6 Ampere-hour capacity Nickel Cadmium rechargeable cells which provide ± 7,2 V to operate the instrument. Their capacity is sufficient to cover a continuous operating time of 18 days. With each bump event read-out this is reduced by approx. 3,5 minutes. The separate battery charger supplied can recharge the cells from a completely discharged condition in 16 hours. The cells are recharged in situ.

The instrument power supply voltage is monitored by a detector circuit which automatically shuts down the instrument if the battery voltage is allowed to fall below ± 6,3 V. This feature prevents the cells being damaged by over discharging and ensures that the recorder does not print-out misleading information. Shut down due to low power supply voltage, can be recognised by an incomplete print-out. The power supply can only be reconnected by resetting the instrument.

Where it is required that the Bump Recorder should operate continuously for longer journeys, an external power supply can replace the built-in supply. It is connected via a 7 pin DIN socket at the rear of the instrument and should supply a voltage of max. +8,4 V — 0 — —8,4 V and min. +6,8 V — 0 — —6,8 V. Current consumption is approx. 10 mA with peaks of 2 A during print-out. A suitable external supply consisting of twelve 10 Ah Nickel Cadmium cells will give a continuous operating time of 45 days.

Specifications 2503

Measuring Ranges:
(See Fig. 4)
Pulse Width: 1 ms to 250 ms
Velocity: 0,3 m/s to 14 m/s
Acceleration: 10 ms^{-2} to 5000 ms^{-2} (1 g to 500 g)

Trigger Level:
Stepwise selectable 10 ms^{-2}, 20, 50, 100, 200, 500, 1000 ms^{-2}

Overall Measuring Accuracy:
With a half sinusoidal pulse and input in one channel, ± 10%
With a half sinusoidal pulse and input on three channels, ± 20% for 90% of possible bump directions. For remaining 10%, accuracy is within —20% to —40%
Additionally ± 1 on last significant digit of read-out

Input Sensitivity:
Calibrated for accelerometer sensitivity 1 pC/ms^{-2} (10 pC/g)

Input Impedance:
> 3 GΩ DC shunt resistance (Charge Input)

Environmental Sensitivity (excluding accelerometer):
Maximum Sinusoidal Vibration:
13 ms^{-2}, 5 Hz to 27 Hz: 0,9 mm pk-pk, 27 Hz to 52 Hz: 50 ms^{-2}, 52 Hz to 500 Hz
Maximum Intermittent Shock:
1000 ms^{-2}
Absolute Maximum Shock:
1500 ms^{-2} withpulse width < 5 ms
Maximum Humidity: 95% RH
Temperature Range: —10°C to + 50°C
(See also under accelerometer)

Radio Frequency Emission:
Within limits specified by STANAG No. 3516 (31-1-69)
Marginally exceeds limits below 300 kHz specified by MIL STD 461A, Notice 4, Limit CE 04 and CE 05, with measuring probe over all three transducer cables. Emission from individual cables within limits. Measuring method specified in MIL STD 462, Notice 3, Method CE 05

Printer:
Prints on 6 mm heat sensitive paper. Each roll will accept approx. 540 complete print-outs

Print Head:
7 dot line. Characters built-up from a 5 × 7 dot matrix

Printing Speed:
Complete print-out of 28 characters and spaces takes 4 s

Internal Clock:
Crystal controlled, accuracy ± 1 minute/week
Time-check print-out selectable each hour or 24 hours

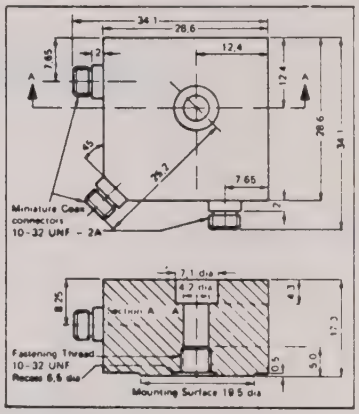
Power Supply:
12 Rechargeable NiCd-Cells, 3,6 Ah total capacity at 20°C
Operating capacity: 18 days continuous with a reduction of 3,5 min. for each print out (at 20°C). At —10°C and + 50°C capacity is 16 days continuous
External power supply requirements:
Connected to 7 pin DIN socket on rear panel
Max.: + 8,4 V — 0 — —8,4 V
Min.: + 6,8 V — 0 — —6,8 V
Automatic switch-off for supply voltage less than ± 6,3 V
Current: 10 mA quiescent, 2 A during print-out
Complies with safety class III of IEC 348

Battery Charger:
B & K Type ZG 0166
Input: 90 to 240 V AC
Output: 400 mA constant current
Time for complete recharge: 16 hours
Complies with safety Class II of IEC 348

Accelerometer:
B & K Type 4321 Triaxial
Sensitivity: 1 pC/ms^{-2} ± 2%
(~ 10 pC/g)
Weight: 55 grams
Mounted resonant frequency: 40 kHz
Transverse resonant frequency: 11 kHz
Maximum ambient temperature: 250°C (500°F)
Maximum shock in any direction:
10000 ms^{-2} (1000 g)

Weight:
Including batteries and accelerometer, approx. 6 kg (13 lb)

Accelerometer Dimensions:



Dimensions:
Height: 86 mm (3,4 in)
Width: 295 mm (11,6 in)
Depth: 254 mm (10,0 in)
Including polyurethane container:
Height: 195 mm (7,7 in)
Width: 420 mm (16,5 in)
Depth: 380 mm (15,0 in)

Accessories Included:
Triaxial Accelerometer Type 4321S
3 Reinforced Accelerometer cables 3 m long AO 0089
Battery Charger ZG 0166
Special 7 pin DIN plug JP 0710 for external power supply
Fuses 2 A Slow VF 0010
1 Packet heat sensitive recording paper QP 0007 (20 rolls)
3 loose paper spools DB 1893
2 Securing straps for container DH 0358
2 Halves Moulded Polyurethane Container KG 0101

Accessories Available:
Reinforced Cable 3 m long AO 0089 (3 required)
Accelerometer Type 4371 (Sensitivity 1 pC/ms^{-2})
Accelerometer Type 4370 (Sensitivity 10 pC/ms^{-2}
High Sensitivity Accelerometer Type 8306 (Sensitivity 1000 pC/ms^{-2}, needs separate + 28 V DC, 2 mA power supply)

2. CONTROLS

2.1. CONTROL PANEL

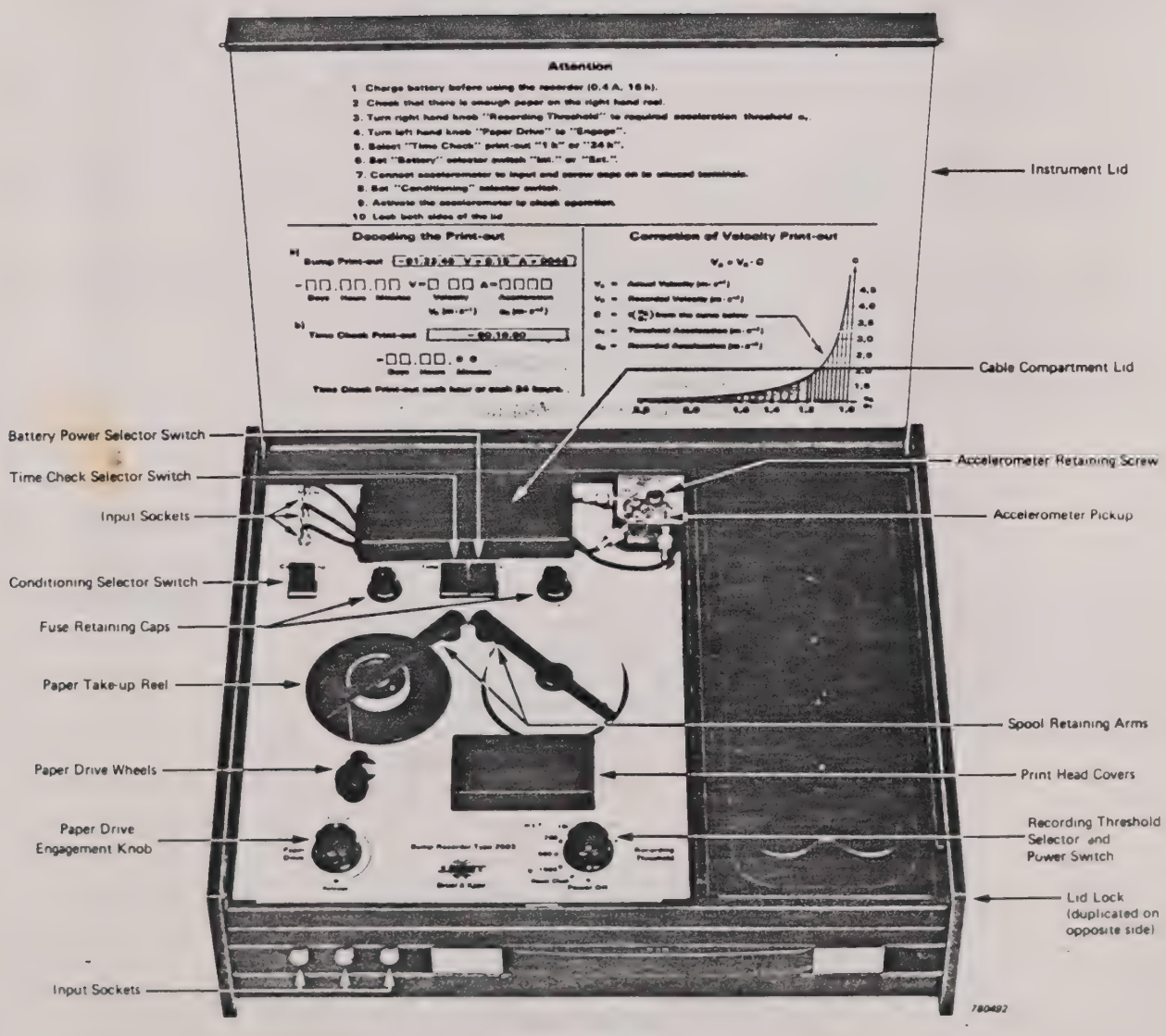


Fig.2.1. Bump Recorder Type 2503

INPUTS: Three miniature sockets accepting standard accelerometer cables from the Triaxial Accelerometer Type 4321 supplied as standard with the

2503. The three inputs are duplicated by three parallel input sockets situated on the front edge of the instrument adjacent to the carrying handle. Avoid contamination of the input sockets by keeping dust caps (supplied) on unused sockets.

CONDITIONING: Toggle switch which conditions the summing amplifier gain in accordance with either one or three input signals. A single input may be connected to any one of the input sockets.

TIME CHECK: Toggle switch which determines whether a time print-out is performed automatically each hour or each 24 hours.

BATTERY: Toggle switch which determines whether the instrument is powered from the internal battery supply or an external supply connected to the multi-pin socket on the rear of the instrument. Refer to Chapter 3.2 for power supply details.

FUSE: Retaining caps holding the two 2A (slow) power supply fuses. Turn counter-clockwise to remove.

PAPER DRIVE: A knob which engages or releases the paper drive wheel and the pressure pad at the print head. Is released to facilitate removal and mounting of the paper strip.

RECORDING THRESHOLD: Knob setting determines the acceleration level above which the recorder processes and prints out bump events. When selecting a threshold level turn the switch from the **Power Off** position ensuring that the switch rests in the **Reset** position momentarily before moving to the required setting. This ensures that the clock is reset to zero. In the **Reset** position the comparator/switch circuit for low battery level is also reset.

2.2. REAR, SIDE AND FRONT PANELS

UNMARKED SOCKET ON REAR PANEL: A 7 pin DIN socket for connection of an external power supply (Max. +8,4 V —0 —minus 8,4; Min. +6,8 V —0 —minus 6,8 V) and the internal battery recharging voltage (400 mA constant current from the B & K battery charger ZG 0166 supplied). Refer to Chpater 3 for details. WARNING: DAMAGE WILL OCCUR IF EXTERNAL POWER SUPPLY IS CONNECTED WITH REVERSED POLARITY. External supplies should be fused.

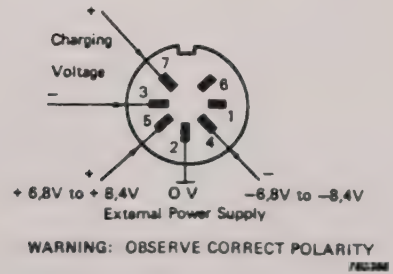


Fig.2.2. Pin Functions of External Power/Charging Socket on rear panel. Socket viewed from outside

LOCK ON BOTH SIDE PANELS:

Can be turned through 180° with thin coin or screwdriver to lock or release the instrument lid.

THREE MINIATURE CONNECTOR SOCKETS ON FRONT PANEL:

Three input sockets wired in parallel with the inputs on the control panel. Keep dust caps on unused sockets.

3. PRELIMINARY

3.1. ENVIRONMENTAL CONDITIONS FOR STORAGE AND OPERATION

The Bump Recorder is housed in a robust aluminium framework and is designed to withstand more severe environmental conditions than normally permitted for electronic measuring instruments. Nevertheless, the instrument should be treated with respect and protected against unnecessarily violent conditions as indicated in the following notes.

3.1.1. Sinusoidal Vibration

Sweeping frequency vibration tests in accordance with MIL STD 810B Method 514—proc.X have been performed on the 2503. The instrument will survive long periods of vibration which does not exceed the levels specified in this test. See Fig.3.1. The accelerometer can tolerate continuous sinusoidal vibration levels up to 500 g (5000 m/s^2)

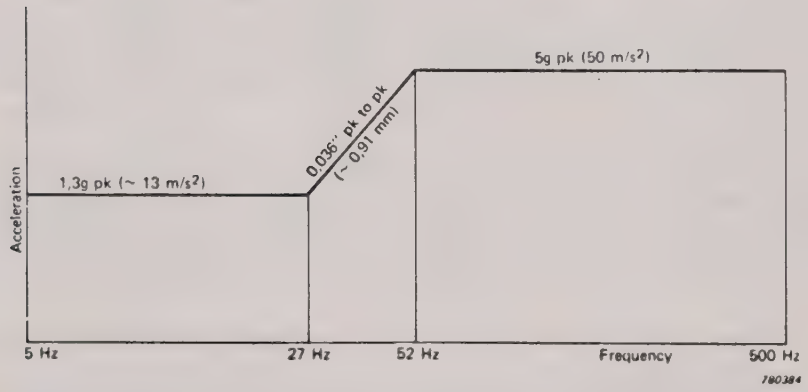


Fig.3.1. Vibration test envelope in accordance with MIL STD 810 B Method 514 — proc. X

3.1.2. Mechanical Shock

The instrument has proved to survive shock tests in accordance with MIL STD 810B - Method 516 - proc.1. Where it is shocked in each of three mutually perpendicular axes with gradually increasing shocks in + and —directions up to a maximum of 150 g (1500 m/s^2) peak, and a pulse width of 5 ms. Only occasional shocks of this magnitude can be tolerated in use. Where high magnitude shocks are to be expected the bump recorder should be mounted inside the polyurethane foam container with the accelerometer pickup mounted rigidly on the object to be monitored. The accelerometer can tolerate shock levels up to 1000 g (10 km/s^2) and thus exceeds the measuring range of the 2503.

3.1.3. Temperature

The 2503 may be used in ambient temperatures between —10°C and +50°C (14°F and 122°F). At —10°C the battery capacity and therefore the operating time is reduced by about 10%. See notes in section 3.2.2 concerning recharging the battery at abnormally low and high temperatures. Storage temperatures between —35°C and +65°C are permissible. The accelerometer pickup may be used in temperatures up to 250°C (500°F).

3.1.4. Humidity

The instrument should be protected from direct rain by covering with a plastic sheet or similar. Packing inside a plastic bag in wet conditions for long periods will encourage condensation and should be avoided as it is difficult to seal the bag completely. The instrument has proved to work satisfactorily under a humidity test according to MIL STD 810B Method 507 — proc.III. During this test the instrument is cycled up and down in temperature in a relative humidity of 90%.

3.2. POWER SUPPLIES

3.2.1. Internal Power Supply:

The internal battery pack consists of twelve General Electric Nickel Cadmium (NiCd.) "Gold Top" cells, or similar, arranged in a positive and negative battery of six series-connected cells. The nominal battery voltage is therefore ± 6 × 1,2 V = ± 7,2 V.

The internal battery can be expected to give at least 18 days (432 hours) continuous operation, assuming a fully charged battery at start. Each complete data printout reduces the capacity by about 3,5 minutes. Note that the battery capacity is reduced at the extremes of the temperature operating range (—10°C and +50°C) to 16 days continuous operation.

Over discharging can severely reduce the lifetime of the NiCd cells. The 2503 is therefore equipped with a detector/switch which disconnects the power supply when the battery voltage falls bow ± 6,3 V. The supply is reconnected after recharging by turning the RECORDING THRESHOLD switch to **Reset** and then back to the required threshold level.

3.2.2. Recharging the Internal Power Supply

Before the Bump Recorder is to be used for important monitoring missions one should be absolutely certain that the internal battery is fully charged. This is accomplished by charging with the Battery Charger ZG 0166 (supplied) for at least 16 hours.

The charger is designed specially for charging the two 7,2 V batteries with a constant current of 400 mA. Time for complete recharge at normal room temperature is approximately 16 hours. The charger may be connected to a 90 V to 240 V, 50 to 60 and 400 Hz supply; select the correct range (90 V to 130 V or 130 V to 240 V) by twisting the voltage selector on the front panel with a screwdriver.

A suitable mains plug should be mounted on the two-conductor mains lead, the phasing is irrelevant. The output of the charger is short circuit protected. The charging voltage is applied by connecting the 7 pin DIN plug on the charger output lead to the corresponding socket on the rear panel of the Bump Recorder. The NiCd battery cannot be overcharged by the ZG 0166 charger; when the charging process is complete excess energy will be dissipated as heat from the battery. For long-term monitoring in-doors where a

Fig.3.2. Battery Charger ZG 0166

mains power supply is available, the instrument can be operated with the battery charger connected and supplying operational power via the batteries.

It is important that the batteries are not charged with the battery charger ZG 0166 in ambient temperatures less than +5°C. At lower temperatures the charging current must be limited, for example: at 0°C, 280 mA. At —10°C, 175 mA. At —20°C, 70 mA. This cannot be done with the battery charger ZG 0166 included.

3.2.3. Care of the Batteries During Long-Term Storage

The batteries can be stored for many years without permanent loss in performance. A charged battery, when left idle, will lose its charge gradually. If left idle for long periods of time, one or more complete charge/discharge cycles will be required to bring it back to top performance.

3.2.4. External Power Supply

Where it is required that the Bump Recorder should be able to monitor continuously for more than 18 days, an external power supply of greater capacity may be connected via the 7-pin DIN socket on the rear panel. The BATTERY switch on the control panel should be switched to **External**. It is not possible to connect an external power supply in parallel with the internal supply. A spare 7 pin DIN plug (JP 0710) is supplied as an accessory to the 2503, it is wired to the external power supply in accordance with Fig.3.3.

The external power supply will be required to supply 2A peaks and should be dual polarity with centre point at 0 V. **It must not be capable of supplying a potential greater than ± 8,4 V.** It should be protected by two 2 A slow blow fuses (BK/ No. VF 0010) situ-

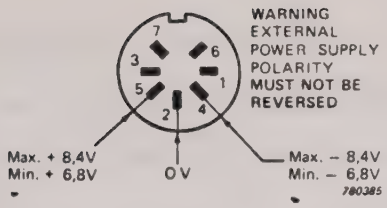


Fig.3.3. Connections to plug JP 0710 for external power supply. Inside (soldering side) of plug shown

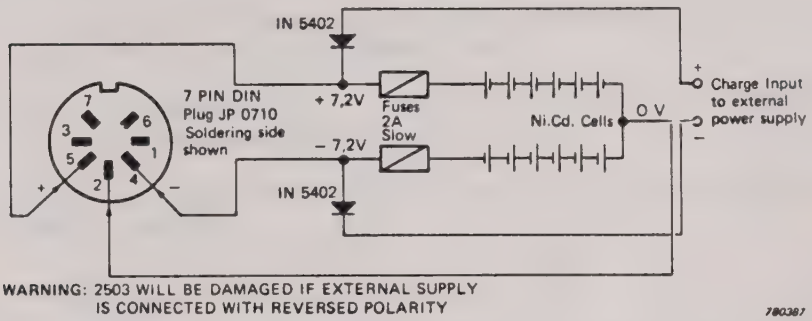


Fig.3.4. External power supply suitable for powering the 2503. The two diodes IN 5402 are recommended for short circuit protection and incorrect polarity at the charge input

ated directly at the output for maximum safety. It is highly recommended that an external power supply is made up from rechargeable NiCd cells as shown in Fig.3.4. Twelve 10 Ah Nickel Cadmium cells will give a continuous operating time of about 45 days. Batteries should not be paralleled as they tend to discharge into each other.

WARNING: 2503 WILL BE DAMAGED IF EXTERNAL SUPPLY IS CONNECTED WITH REVERSED POLARITY

It should be noted that the external power supply is **not** protected by the fuses in the 2503. It will be protected against excessive discharge by the instrument by the sensor in the 2503 which shuts down the instrument if the battery voltage falls below ± 6,3 V. The supply is reconnected by turning the RECORDING THRESHOLD switch to **Reset** after recharging the batteries, and then selecting the required threshold setting. The normal quiescent current for the instrument is only 10 mA while the battery is called upon to supply 2A peaks during print-out.

3.2.5. Battery Lifetime and Replacement

The batteries used in the 2503 are a special type which give a significantly longer lifetime than ordinary NiCd cells. Each cell is specially selected and matched to give a balanced charge and discharge cycle. Please refer to the Service Instruction Manual for details of battery pack replacement.

3.3. LOADING THE RECORDING PAPER

A full roll of recording paper should always be fitted prior to the recorder being used for anything more than short laboratory investigations.

1. Turn the PAPER DRIVE knob to **Release**

2. Swing the two spool retaining arms aside giving access to the two paper reels

3. Press a full roll of heat sensitive recording paper (20 rolls = QP 0007) on to the righthand paper reel

4. Draw out 10 to 20 cm of paper and enter it edgewise through the slot between the print-head covers.

5. Pass the paper between the paper drive wheels and then thread it onto the loose paper reel spool on the paper take-up reel.

6. Turn the take-up reel two or three turns by hand to ensure that the paper strip is wound tightly onto the spool.

7. Reposition the spool retaining arms over the two reels and turn the PAPER DRIVE knob to **Engage.**

3.4. SETTING THE CONTROLS

3.4.1. CONDITIONING Selector Switch

This switch controls the gain of the summing amplifier; it should be set to **3 Inputs** when all three outputs of the triaxial accelerometer pickup type 4321 are connected to the bump recorder. When a single accelerometer channel is connected to any of the **Input** sockets the selector switch should be set to **1 Input** to obtain best measuring accuracy.

3.4.2. TIME CHECK Selector Switch

A time check print-out every hour or 24 hours is programmed into the 2503's normal operation in order to show that the instrument has been operational during the monitoring period. Slightly better battery and paper economy will be obtained if the switch is set to **24 hours** while in the **1 hour** position the time of battery run-down or the disconnection of an external power supply will be more accurately indicated.

3.4.3. BATTERY Selector Switch

Set this switch according to whether the 2503 is to be powered from the **Internal** battery supply or a power supply connected to the **External** power/charging socket on the rear panel of the instrument.

3.4.4. RECORDING THRESHOLD Switch

The setting of this knob determines the bump level at which the print-out is activated. The lower the level chosen, the greater the probability that the instrument will be triggered during the journey which it is set to monitor. The threshold level should normally be set to a bump level that if exceeded can be expected to threaten the integrity of the item being monitored. Therefore all insignificant bumps are neglected. The goods item will in normal circumstances arrive at its destination with a Bump Recorder containing very few or no bump print outs. **If the threshold level is set artificially low with respect to the expected transport conditions then the recording tape will be quickly filled**

with insignificant data so that subsequent, possibly serious, bump events will not be recorded.

The probability of bumps occurring as a function of bump amplitude is demonstrated in Fig.3.5 which plots measurements made on the load surface of a motor-truck and a trailer.

When setting up the threshold level from the **Power Off** position the switch should be allowed to rest momentarily in the **Reset** position so as to be sure that the clock is set to zero.

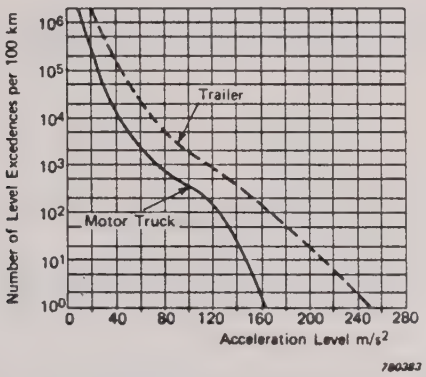


Fig.3.5. Number of level excedances per 100 km of a specific test route. Accelerometers were mounted on the loading surfaces of a motor truck and a trailer. Source: Article entitled "Erchütterungen Auf der Ladefläche verschiedener Lkws Sattelauflieger und Anhänger" by W. Hoppe and J. Gerok. Printed in "Der Versuch und Forschungsingenieur" 1974. Heft 4. Pages 32 to 36

3.5. MOUNTING THE ACCELEROMETER

Because the Triaxial Accelerometer Type 4321 measures simultaneously in three mutually perpendicular directions the Bump Recorder is able to resolve the level of bumps occurring in any random direction. Therefore the accelerometer may be mounted at any convenient angle. The mounting position selected should be on a flat surface on an critical part of the object to be monitored.

The most reliable method of mounting is by a 4 mm screw passed through the accelerometer body or by means of a 10-32 UNF stud screwed into the accelerometer's base or side. A suitable screw and studs are supplied. This method requires that the measuring point is drilled and tapped with either a 4 mm or 10-32 UNF thread. If this is not possible the cementing stud (DB 0756) supplied with the accelerometer accessories can be cemented to the measuring point. An Epoxy or Cyanoacrylate cement should be used. Alternatively a thin double-sided adhesive tape can be used. Suitable discs of this tape are available from B & K under part No. DU 0079.

It is not normally advisable to use the 2503 with the accelerometer mounted on the mounting point in the instrument case. If the instrument is packed in a shock absorbing packing material, for example, the moulded polyurethane foam container supplied, then the bumps measured will have been attenuated by this material. Remember that the bump levels measured by the instrument are the levels experienced by the accelerome-

ter itself, and the most accurate readings will be obtained by attaching the accelerometer directly to the measuring point of interest.

3.6. ACCELEROMETER CABLES

Three 1,2 m long low noise accelerometer cables (AO 0038) are supplied as standard equipment with the accelerometer. These will be used when the accelerometer is mounted inside the instrument case or close to it. The cable run between the accelerometer and the 2503 should be taped down and not allowed to hang loose.

Three 3 m long reinforced accelerometer cables (AO 0089) are also supplied with the Bump Recorder. These will be used where it is possible that the cable can be exposed to rough handling.

3.6.1. Longer Cables

Where longer cable runs are required three alternatives are available.

1. Order additional standard cables (as above) and join them together with extension connector JJ 0032. (Set of 25 extension connectors available under part No. UA 0186)

2. Order the required length of accelerometer cable AC 0200 and a miniature plug set UA 0129 which also contains an assembly tool. Individual cables can then be made up as desired. Longer reinforced cables cannot be made up in this way.

3. Special lengths of ordinary and reinforced cable fitted with miniature plugs can be supplied on special order.

Note: Only proper coaxial low-noise accelerometer cables may be used with the 2503.

3.6.2. Connectors and Humidity

Where the accelerometer and external cable connectors are likely to be subjected to very humid or wet conditions the connector should be sealed by an acid-free room temperature vulcanizing silicon rubber (RTV) solution. A suitable solution is Dow Corning Silastic RTV 738 which is available in tubes. Alternatively the cable connector may be dipped into a Silicon grease (i.e. Dow Corning Silicon Compound No. 7) before assembly.

3.7. SEALING AND MOUNTING THE INSTRUMENT

The instrument lid is fastened by twisting the two slotted screws in the side panels through 180° into the **Locked** position. By tying a wire over the lid and securing it through the two 2 mm dia holes in the front and back rail of the instrument the lid can be sealed with lead seals to guard against unauthorised interference.

In normal circumstances it will be most convenient to pack the 2503 into the moulded polyurethane foam container supplied. This should, in-turn, be fastened inside the package to be monitored by means of the two straps supplied, or by metal strips made to suit the particular application. The main requirement is that the Bump Recorder must be restrained from falling around during use.

Remember that accelerometer connection cables should be taped down and not allowed to hang loose.

It the 2503 is to be used out in the open or in very humid conditions the comments in section 3.1.4 should be noted.

3.8. ALTERNATIVE ACCELEROMETERS

Fig.3.4. Alternative accelerometer pickups which can be used conveniently with the Bump Recorder

The input of the 2503 is designed for use with piezoelectric accelerometers having a sensitivity of 1pC/ms^{-2}) (~10pC/g). When accelerometers having another sensitivity are used, the levels read out and the threshold levels must be multiplied by a corresponding factor (F).

$$F = \frac{1\text{pC/ms}^{-2}}{\text{Sensitivity of Accelerometer Used (pC/ms}^{-2})}$$

If it is wished to use individual (single axis) accelerometers having the same sensitivity as the triaxial type 4321 (supplied), B & K type 4371 is recommended.

The sensitivity of the Bump Recorder can be increased by a factor of 10 by using a single or three accelerometers of the type 4370. This has a sensitivity of 10 pC/ms^{-2} (~ 100 pC/g). Remember to multiply the levels read out and the threshold levels by 0,1.

Using one or three Low g Accelerometers Type 8306, the Bump Recorder sensitivity is increased a thousand times, making it suitable for monitoring ground vibrations due to heavy traffic, explosive detonations, seismic activity etc. With this accelerometer the acceleration measuring range covers 0,01 to 5 m/s^2 (0,001 to 0,5 g).

The Accelerometer type 8306 requires a separate power supply of nominally 28 V DC, 2 mA, which is conveniently provided by three 9 V transistor radio batteries wired in series. The power supply input to the 8306 accelerometer is via a miniature coaxial socket. A simple power supply cable is made from a standard accelerometer cable with one connector cut off and the free end soldered to the batteries.

4. READING THE RESULTS

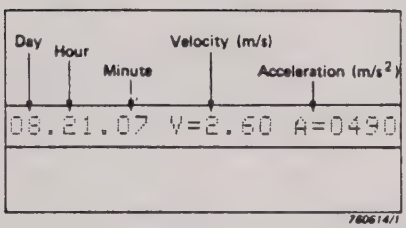


Fig.4.1. A typical print-out from the 2503

The relative time of occurrence of each bump event in days, hours, and minutes precedes the maximum velocity V(m/s) and maximum acceleration A m/s^2) printed out. On unpacking the bump recorder after a journey the THRESHOLD LEVEL switch should be turned to a low level and the accelerometer bumped. If a readout results this shows that the instrument has not switched itself off due to too low battery voltage. If the instrument does not read out, the latest time-readout on the tape will give an indication of how long the recorder has been inactive.

4.1. VELOCITY PRINT-OUT CORRECTION

In cases where the velocity level printed out only marginally exceeds the threshold level chosen, an integration error will have occurred as explained in Chapter 1. The correct velocity level can be found by multiplying the level printed out by a factor (C) found from the chart in Fig.4.2.

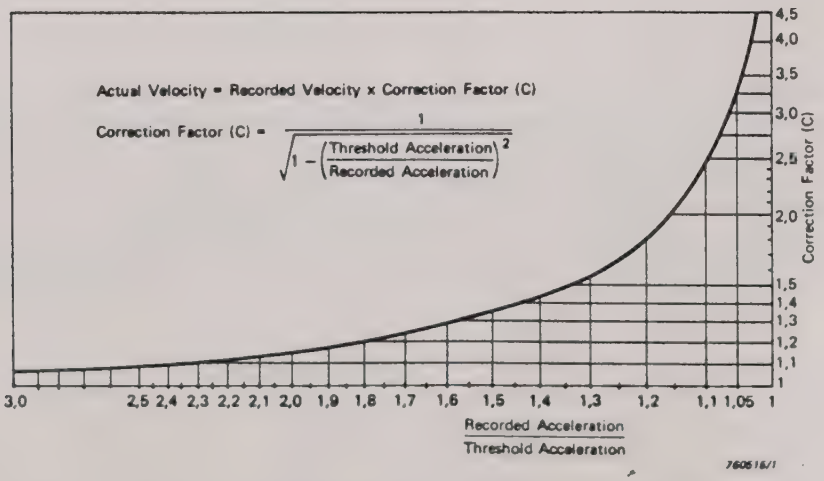


Fig.4.2. Chart for determining the actual impact velocity from the velocity level printed out when the threshold level is marginally exceeded

4.2. OPERATING RANGE

The 2503 is designed to record the full range of shocks likely to occur during the transportation of goods. The measuring limits are shown graphically in Fig.4.3. Recorded levels lying outside this area cannot be relied upon to be accurate.

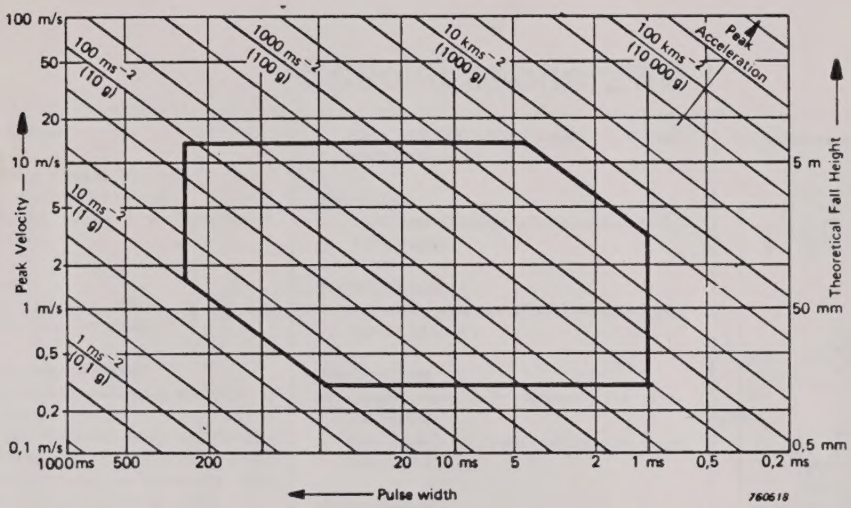


Fig.4.3. Operating ranges for the Bump Recorder Type 2503. The right hand scale of Theoretical Drop Height is sometimes used as a measure of maximum velocity. The Theoretical Drop Height $h = v^2/2g$ where v = maximum velocity and g = the acceleration due to gravity

The chart in Fig.4.3 can also be used to determine time duration of a shock pulse exceeding the threshold level. The intersection of the corresponding velocity and acceleration lines can be traced down to the X axis of the chart which indicates the pulse width.

4.2.1. Blocking of the Readout for Insignificant Velocity Levels

The accelerometer may often be subjected to bumps of insignificant energy level, but which nevertheless exceed the selected trigger acceleration level (i.e. having very short pulse width). To avoid wasting paper and battery power on printing-out these insignificant bumps a readout-blocking device comes into action for velocity levels lower than 0,01 m/s. The action of this device can be seen by tapping the accelerometer lightly with a pencil (RECORDING THRESHOLD set to 10 m/s^2). The paper drive will judder slightly indicating that the threshold level has been exceeded but the velocity level is below 0,01 m/s.

Where it is required that the Bump Recorder should operate continuously for longer journeys, an external power supply can replace the built-in supply. It is connected via a 7 pin DIN socket at the rear of the instrument and should supply a voltage of max. +8,4 V — 0 — —8,4 V and min. +6,8 V — 0 — —6,8 V. Current consumption is approx. 10 mA with peaks of 2 A during print-out. A suitable external supply consisting of twelve 10 Ah Nickel Cadmium cells will give a continuous operating time of 45 days.

Specifications 2503

Measuring Ranges:
(See Fig.4)
Pulse Width: 1 ms to 250 ms
Velocity: 0,3 m/s to 14 m/s
Acceleration: 10 ms^{-2} to 5000 ms^{-2} (1 g to 500 g)

Trigger Level:
Stepwise selectable 10 ms^{-2}, 20, 50, 100, 200, 500, 1000 ms^{-2}

Overall Measuring Accuracy:
With a half sinusoidal pulse and input in one channel, ± 10%
With a half sinusoidal pulse and input on three channels, ± 20% for 90% of possible bump directions. For remaining 10%, accuracy is within —20% to —40%
Additionally ± 1 on last significant digit of read-out

Input Sensitivity:
Calibrated for accelerometer sensitivity 1 pC/ms^{-2} (10 pC/g)

Input Impedance:
> 3 GΩ DC shunt resistance (Charge Input)

Environmental Limits (excluding accelerometer):
Maximum Sinusoidal Vibration:
13 ms^{-2}, 5 Hz to 27 Hz;
0,9 mm pk-pk, 27 Hz to 52 Hz;
50 ms^{-2}, 52 Hz to 500 Hz
Maximum Intermittent Shock:
1000 ms^{-2}
Absolute Maximum Shock:
1500 ms^{-2} withpulse width < 5 ms
Maximum Humidity: 95% RH
Temperature Range: —10°C to + 50°C
(See also under accelerometer)

Radio Frequency Emission:
Within limits specified by STANAG No. 3516 (31-1-69)
Marginally exceeds limits below 300 kHz specified by MIL STD 461A, Notice 4, Limit CE 04 and CE 05, with measuring probe over all three transducer cables. Emission from individual cables within limits. Measuring method specified in MIL STD 462, Notice 3, Method CE 05

Printer:
Prints on 6 mm heat sensitive paper. Each roll will accept approx. 540 complete print-outs

Print Head:
7 dot line. Characters built-up from a 5 × 7 dot matrix

Printing Speed:
Complete print-out of 28 characters and spaces takes 4 s

Internal Clock:
Crystal controlled, accuracy ± 1 minute/week
Time-check print-out selectable each hour or 24 hours

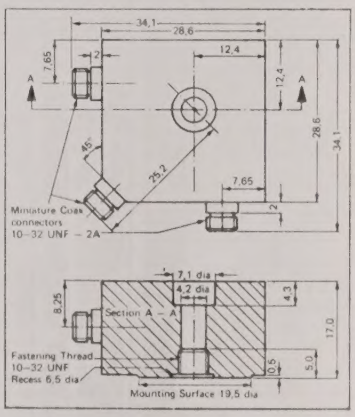
Power Supply:
12 Rechargeable NiCd-Cells, 3,6 Ah total capacity at 20°C
Operating capacity: 18 days continuous with a reduction of 3,5 min. for each print out (at 20°C). At —10°C and + 50°C capacity is 16 days continuous
External power supply requirements:
Connected to 7 pin DIN socket on rear panel
Max.: + 8,4 V — 0 — —8,4 V
Min.: + 6,8 V — 0 — —6,8 V
Automatic switch-off for supply voltage less than ± 6,3 V
Current: 10 mA quiescent, 2 A during print-out

Battery Charger:
B & K Type ZG 0166
Input: 90 to 240 V AC
Output: 400 mA constant current
Time for complete recharge: 16 hours
Complies with safety Class II of IEC 348

Accelerometer:
B & K Type 4321 Triaxial
Sensitivity: 1 pC/ms^{-2} ± 2%
(~ 10 pC/g)
Weight: 55 grams
Mounted resonant frequency: 40 kHz
Transverse resonant frequency: 11 kHz
Maximum ambient temperature: 250°C (500°F)
Maximum shock in any direction:
10000 ms^{-2} (1000 g)

Weight:
Including batteries and accelerometer, approx. 6 kg (13 lb)

Accelerometer Dimensions:



Dimensions:
Height: 86 mm (3,4 in)
Width: 295 mm (11,6 in)
Depth: 254 mm (10,0 in)
Including polyurethane container:
Height: 195 mm (7,7 in)
Width: 420 mm (16,5 in)
Depth: 380 mm (15,0 in)

Accessories Included:
Triaxial Accelerometer Type 4321S
3 Reinforced Accelerometer cables 3 m long AO 0089
Battery Charger ZG 0166
Special 7 pin DIN plug JP 0710 for external power supply
Fuses 2 A Slow VF 0010
1 Packet heat sensitive recording paper QP 0007 (20 rolls)
3 loose paper spools DB 1893
2 Securing straps for container DH 0358
2 Halves Moulded Polyurethane Container KG 0101

Accessories Available:
Reinforced Cable 3 m long AO 0089 (3 required)
Accelerometer Type 4371 (Sensitivity 1 pC/ms^{-2})
Accelerometer Type 4370 (Sensitivity 10 pC/ms^{-2}
High Sensitivity Accelerometer Type 8306 (Sensitivity 1000 pC/ms^{-2}; needs separate + 28 V DC, 2 mA power supply)